Report from T-992 (Radiation-Hard Sensors for the SLHC) at FTBF

Ryan Rivera
Computing Sector/Electronic Systems Engineering, Fermilab
On behalf of T-992 collaboration

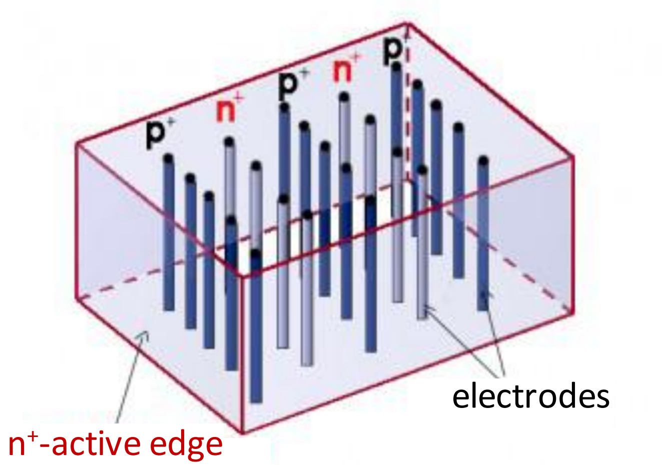
All Experimenters Meeting
April 30, 2012

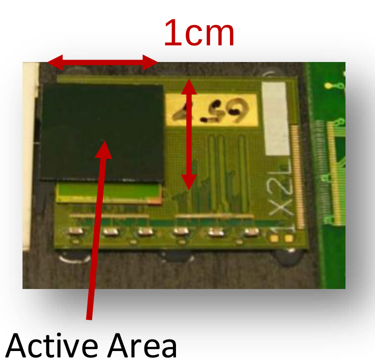
Motivation

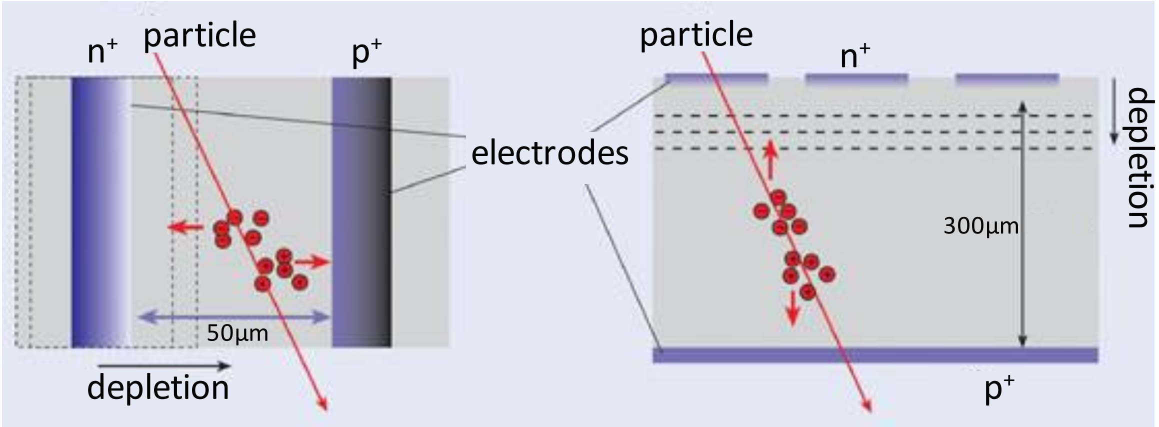
- Goal is to test candidates for the SLHC pixel upgrade, with current focus on:
  - Diamond sensors
  - 3D sensors
- Conclusions are based on performance before and after irradiation.
- Today we will discuss our April run and the ongoing data analysis.

3D vs. Diamond

- **3D Pixel Sensors**
  - Array of p^+ and n^+ electrode columns penetrates the bulk silicon
  - 3D Advantages:
    - Shorter charge collection path
    - Lower full-depletion voltage
    - Less carrier trapping
    - Faster charge collection



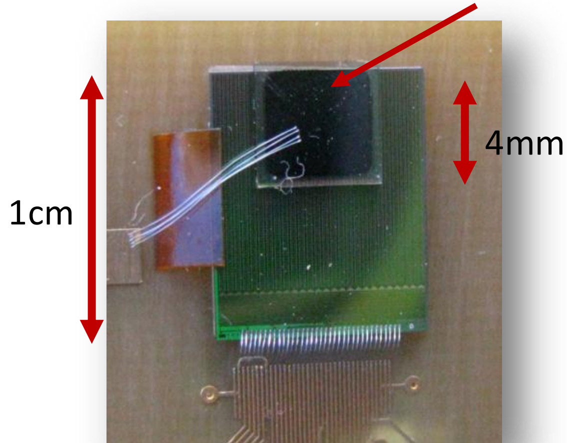


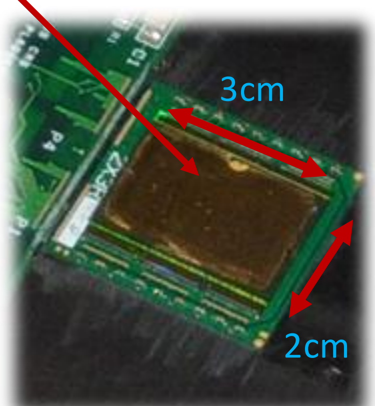


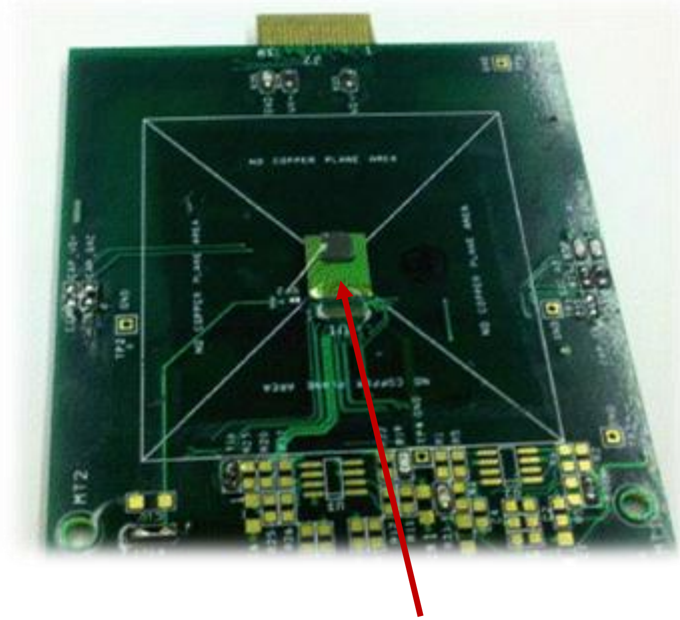
3D vs. Diamond Cont.

- **Diamond Pixel Sensors**
  - monocrystal and polycrystal sensors
  - Diamond Advantages:
    - Large band gap and high displacement energy, so low noise
    - Fast charge collection compared to silicon
    - No thermally generated leakage current

Active Area



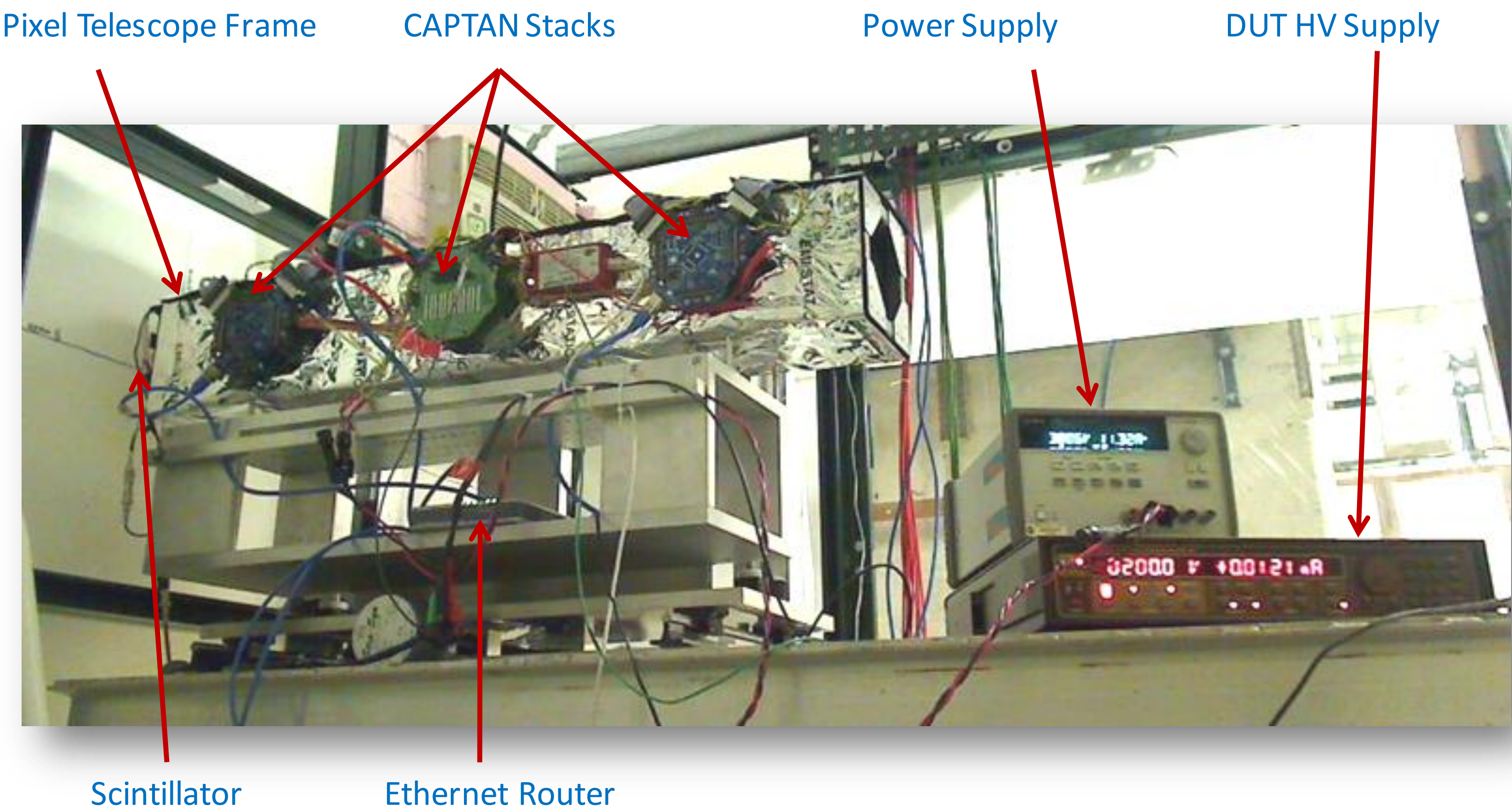




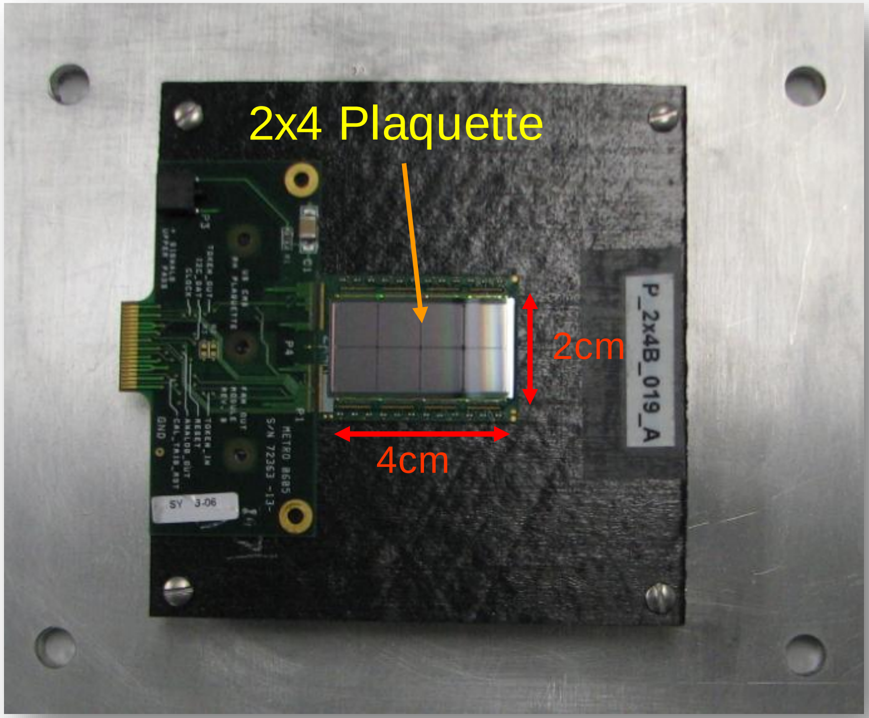
Readout chip and sensor on DUT carrier card

The Setup

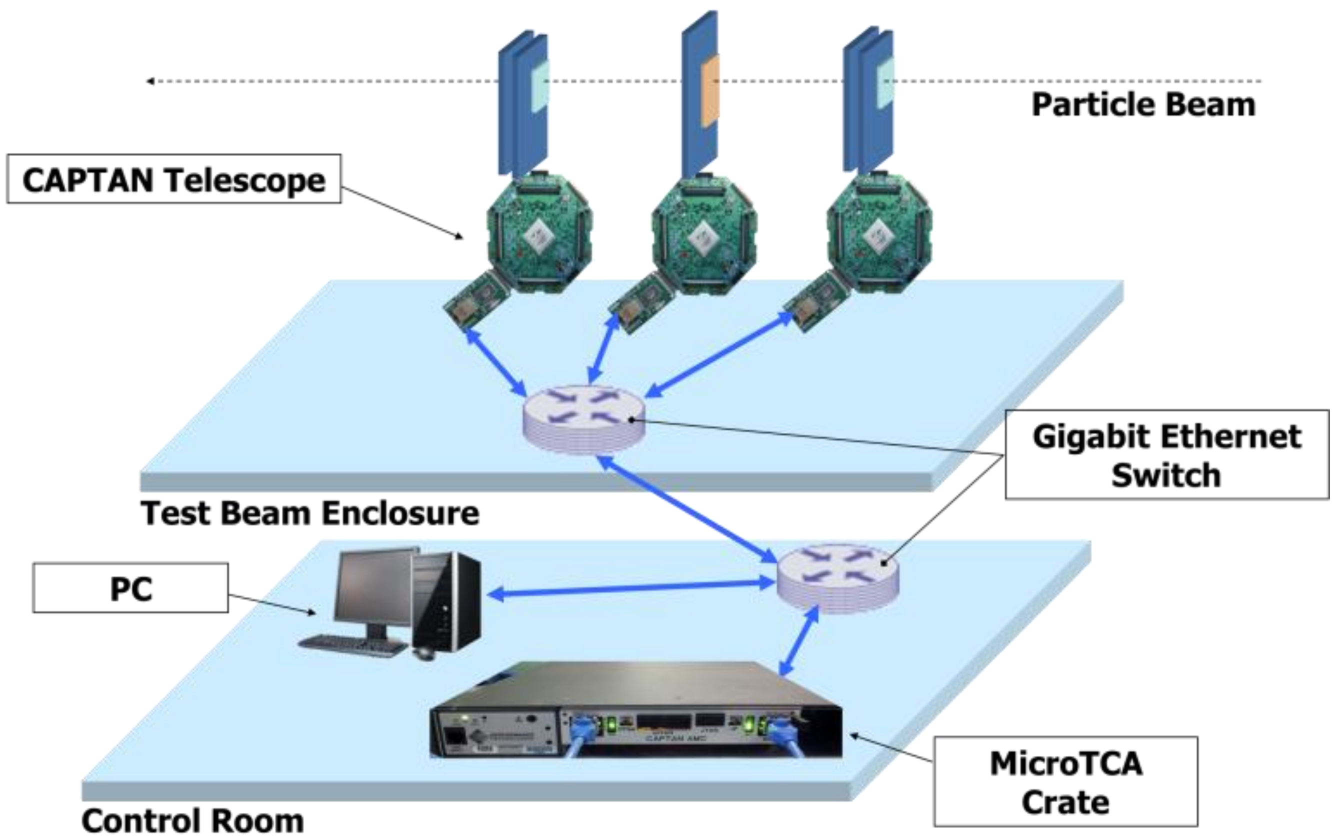
The CAPTAN pixel telescope is 8 silicon pixel planes leftover from CMS, with space for 2 DUTs in the middle. Pixel size is 100 µm x 150 µm. Projected track resolution on DUT is 6-10 µm. Data acquisition with the CAPTAN system.



Telescope Silicon Detector



Pixel Telescope Overview

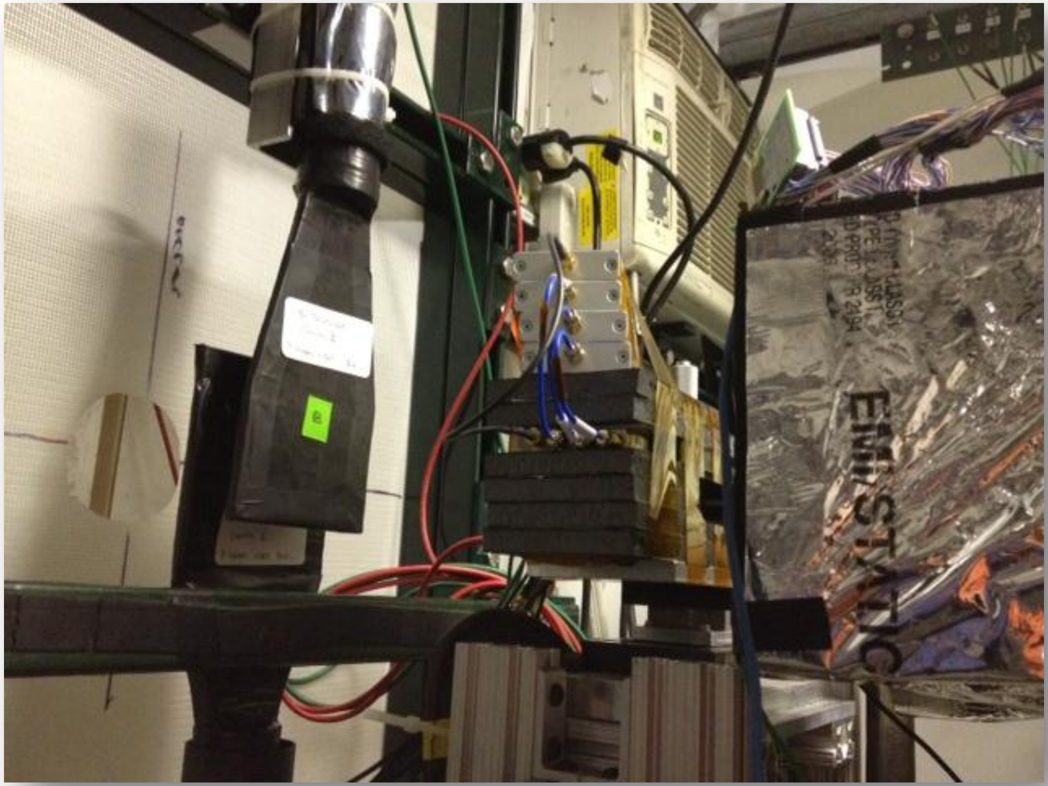


An Aside – Part I

- First attempt at real-time event assembly using MicroTCA architecture:

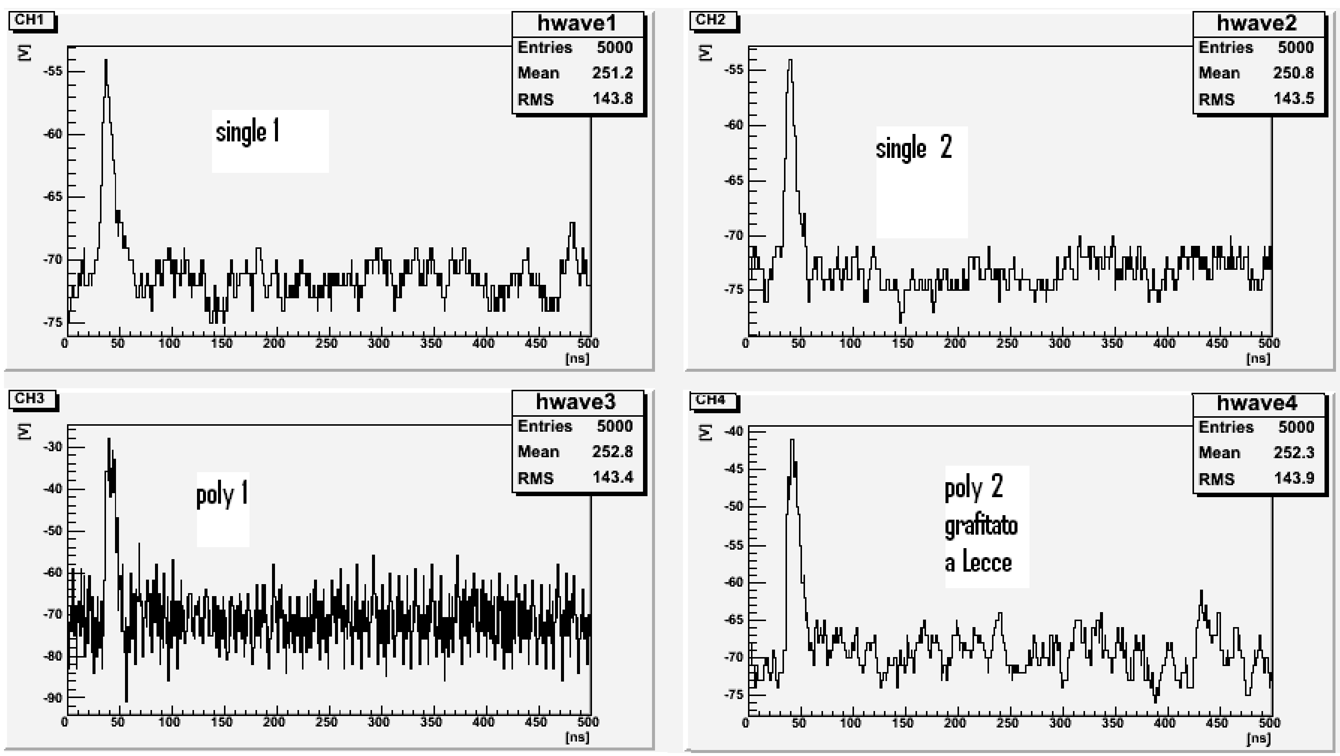
An Aside – Part II

- INFN DIAPIX Diamond Timing Study
  - Goal is to characterize signal pulse height, rise time, and noise

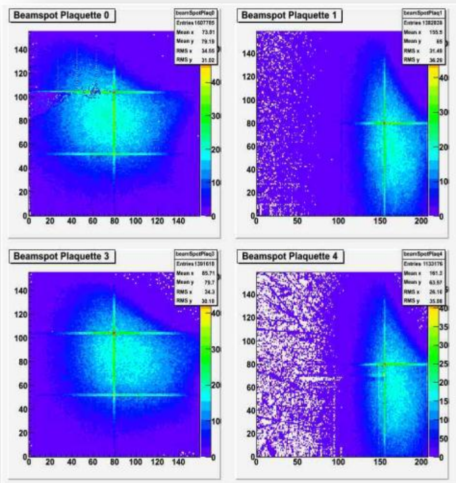


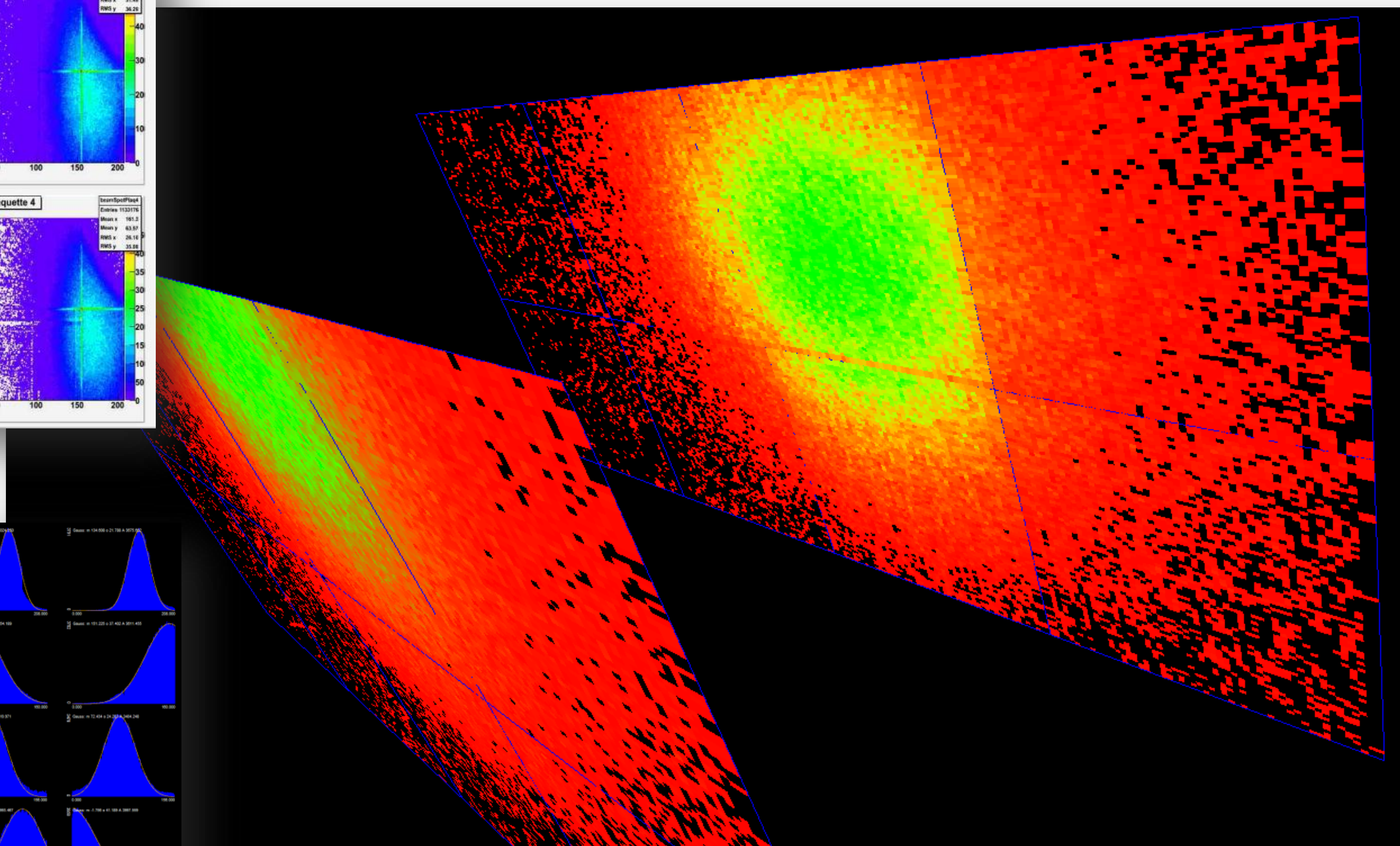
INFN Diamond Timing Study Cont.

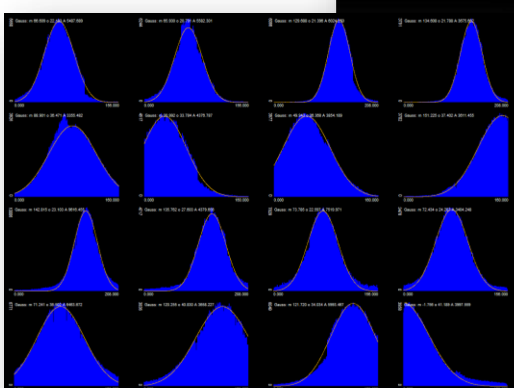
- Still working on analysis, but have data from 2 single crystals and 2 poly crystals (sampling with 1GHz scope).



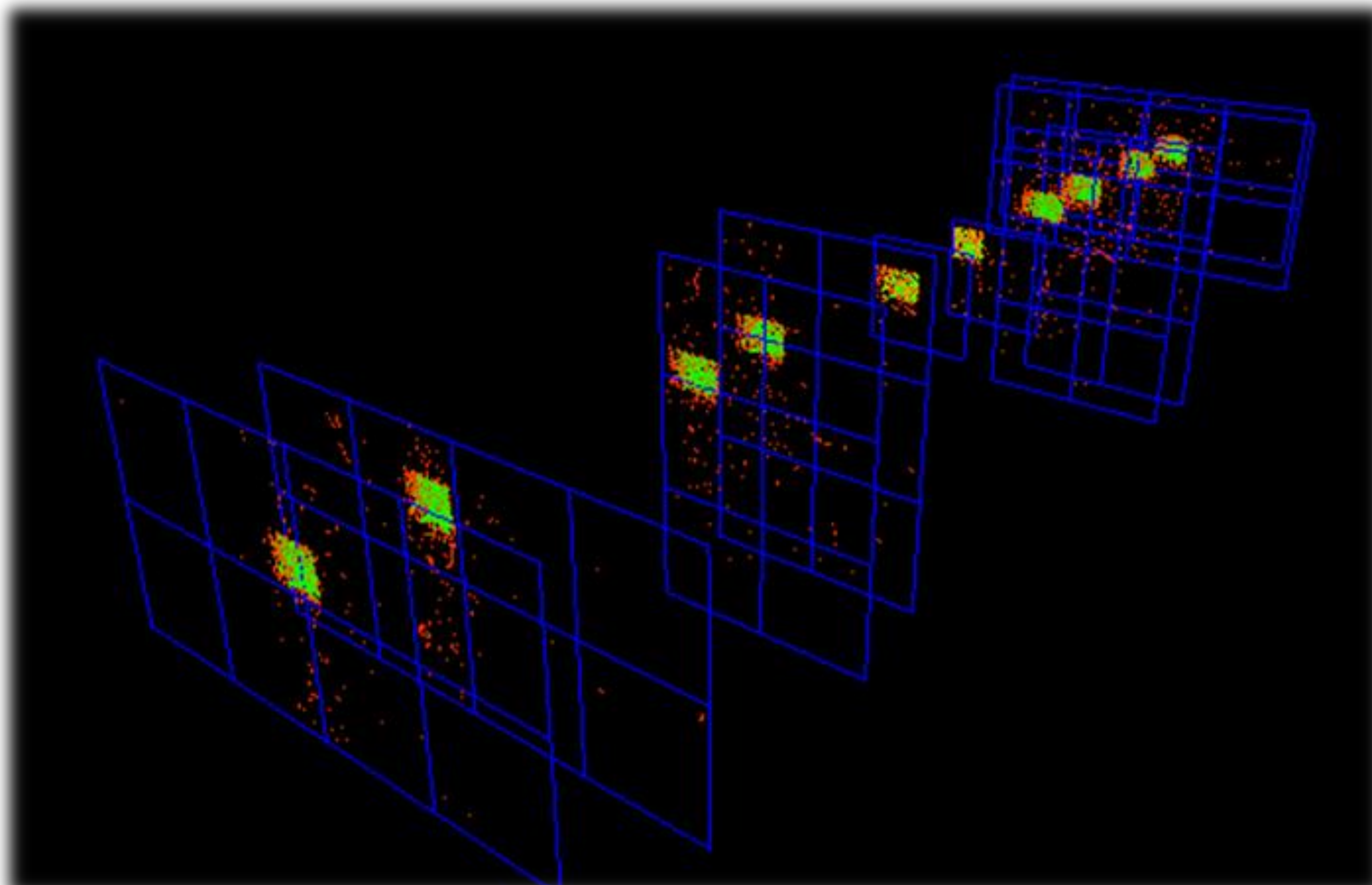
Returning to the pixel telescope - Immediate Data Quality Feedback



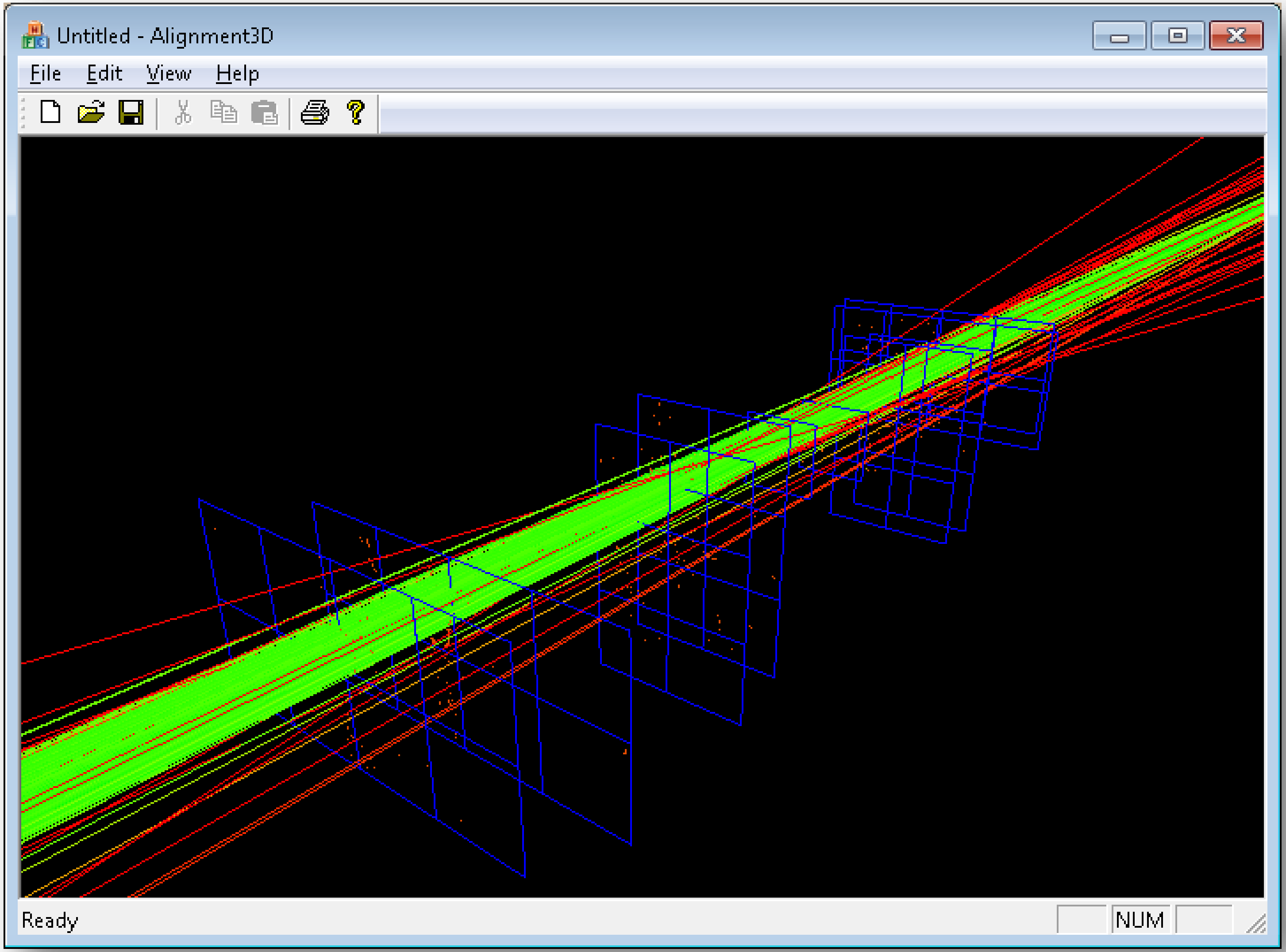




Alignment



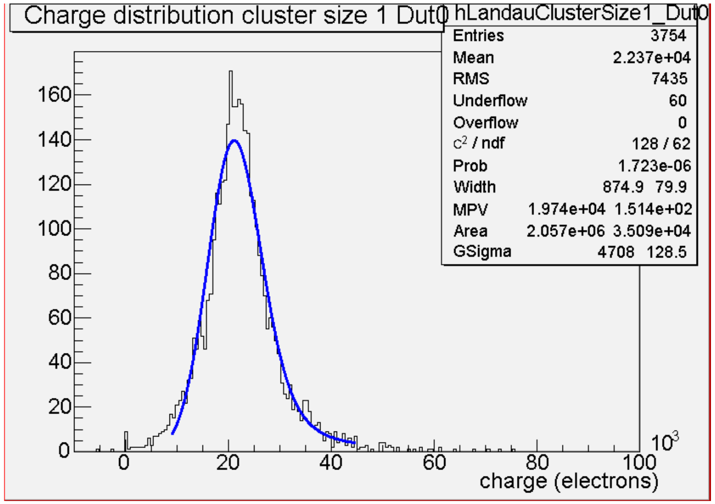
Tracking

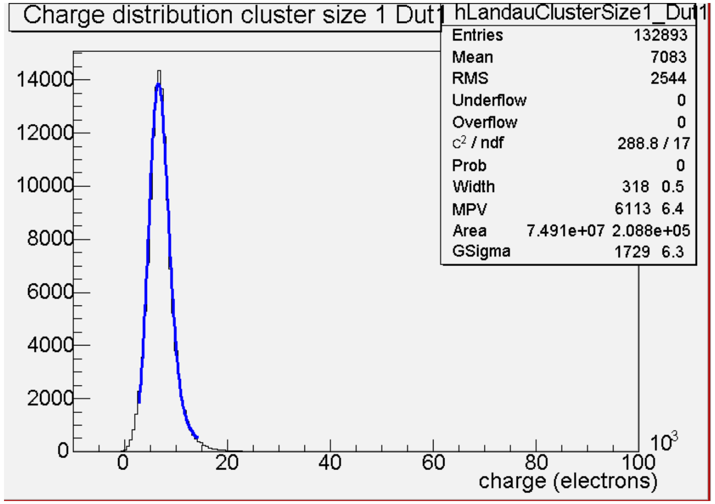


Preliminary Results for Diamonds

- **PLT S32A** – 500 μm thick (un-irradiated) monocrystal. Tested good at CU (except for one missing column). Expected to put out ~18000 e^-.
- **E6-DDL-M1** – 500 μm thick mono irradiated with 3.6×10^{14} (800 MeV) p/cm2 in August 2011. Bench tested at CU to put out ~14400 e^- after irradiation (& before pixelation).
- **LC500** – 500 μm thick (un-irradiated) polycrystal. Bench tested at CU to put out ~6192 e^- before pixelation.
- **LC750** – 750 μm thick E6 poly irradiated with 3.2×10^{14} (800 MeV) p/cm2 in December 2011. Should put out < 7270 e^-.
- **LIMHP-DM-M2** – LIMHP mono polished. Known to put out little charge.

Charge Performance of Mono Sensors

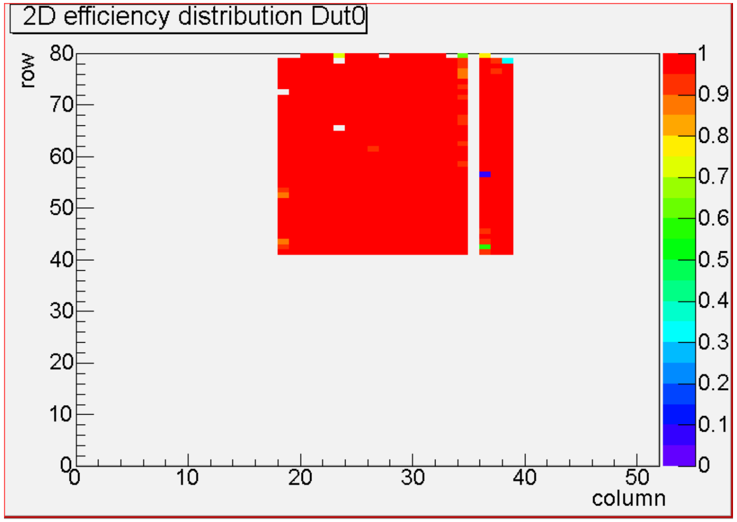


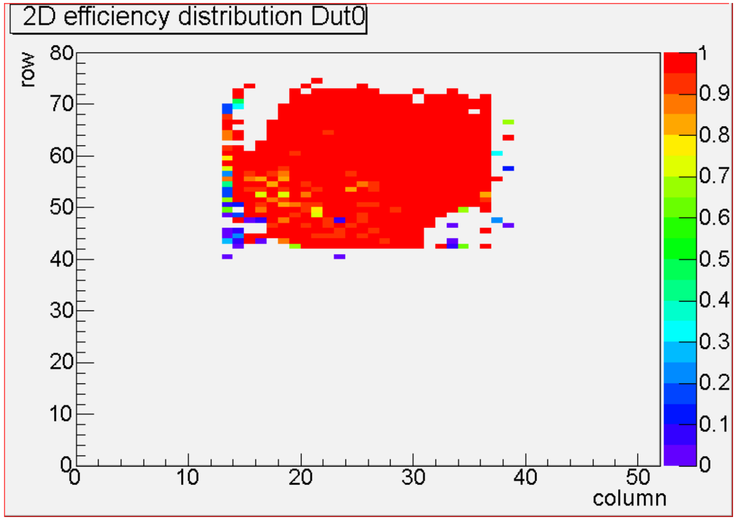


- **PLT S32A** – Produces 22370 e^- on average (24% more than expected). Calibration issues? Under investigation.

- **E6-DDL-M1** – Produces 7080 e^- on average. About 50% of what was expected (from test bench measurement after irradiation). Will investigate further at CU (arrived freshly bumped one day before end of run).

Efficiency of Mono Sensors

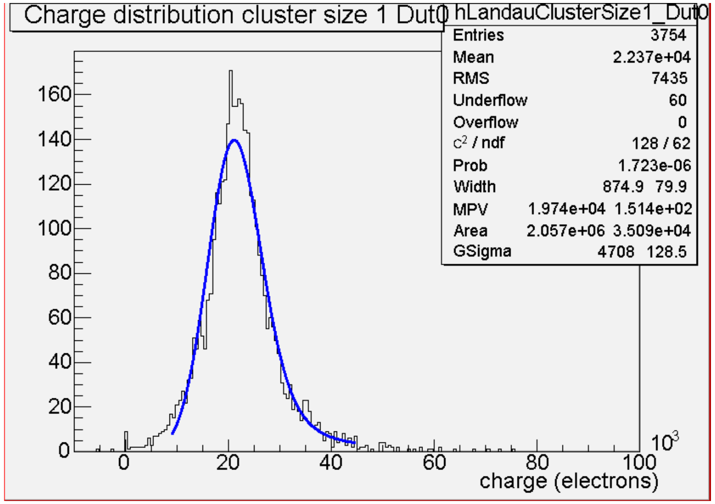


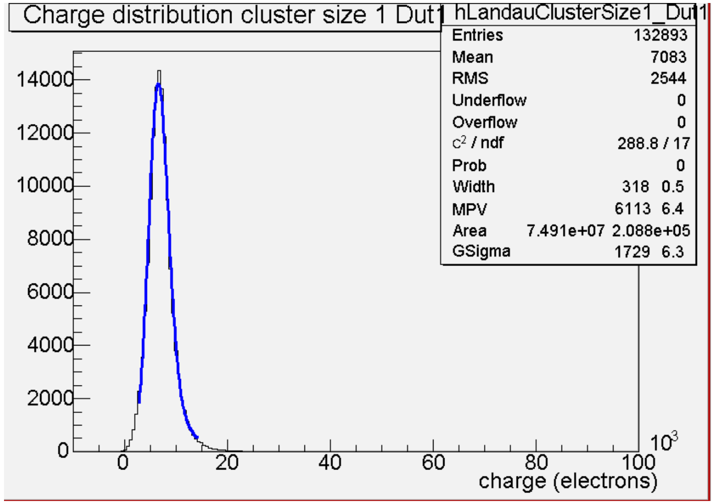


- **PLT S32A** – Other than dead column, efficiency of sensor >99% for wide range of register settings, voltages.

- **E6-DDL-M1** – Known problem with bumps in upper left/lower right corner. Remaining pixels are ~94% efficient after irradiation (correlates with low charge on previous slide – perhaps registers/trims not yet optimized).

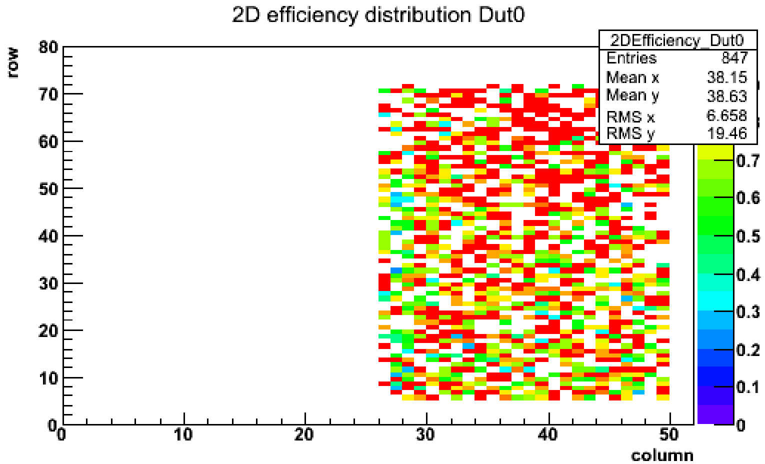
Charge Performance of Irradiated Poly Sensor



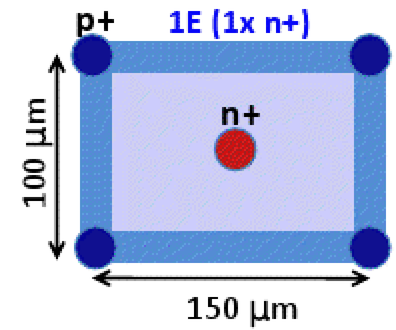


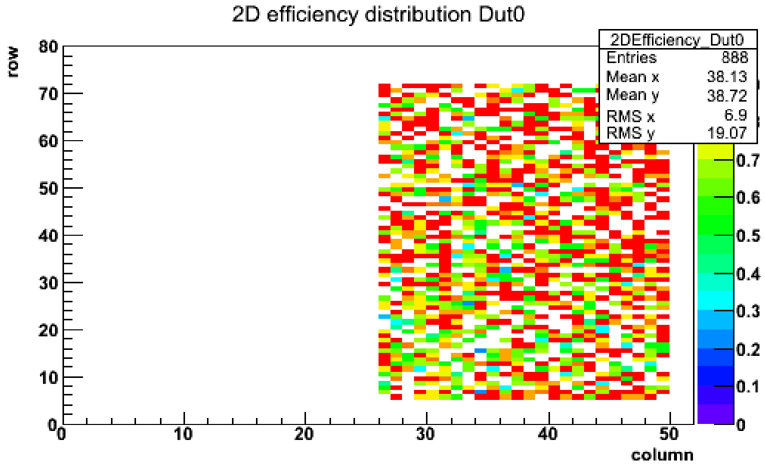
- **LC750** – Puts out ~4730 e^- on average. Not out of line with expected degradation from 7270 e^- for irradiation of 3.2×10^{14} p/cm^2.
- Efficiency ~81% when poorly bumped part of ROC excluded (issue known before irradiation - 1st try at pixelation with full 4k mask). Consistent with amount of charge put out by sensor – clear we need a ROC with lower thresholds for diamond sensors (especially after irradiation).

Preliminary Efficiency of 3D Sensors

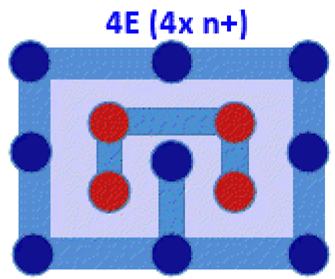


- **FBK_1E_2_W8** – irradiated with 1E15 p/cm^2

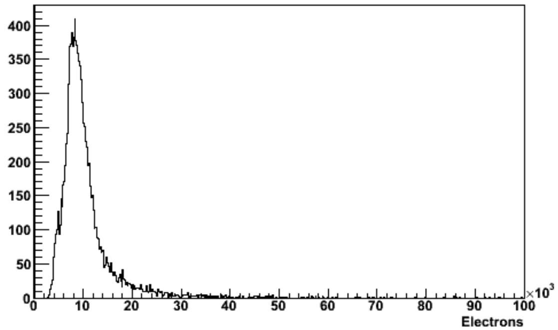


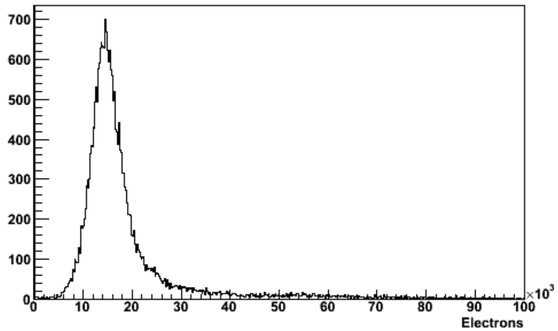


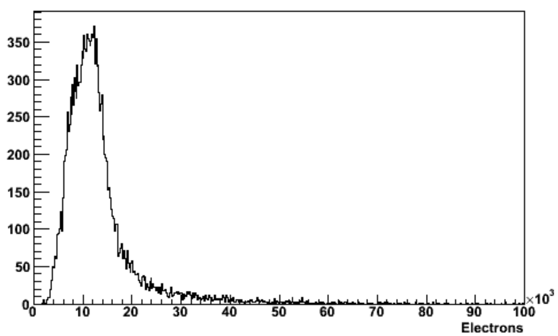
- **FBK_4E_14_W8** – irradiated with 1E15 p/cm^2



Charge Performance of Irradiated 3D



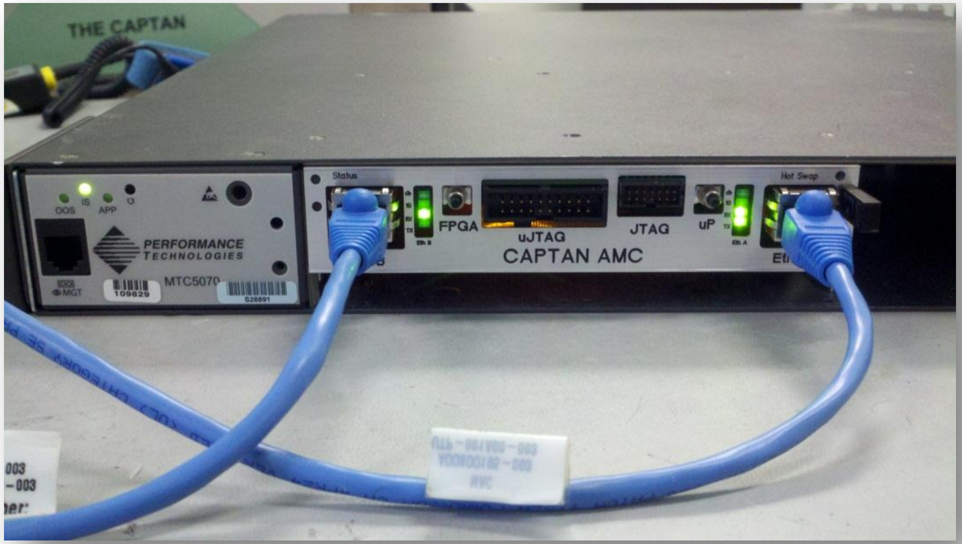




- **FBK_1E_1** – 1E sensor.
  5E15 p/cm^2
  Produces ~10000 e^-
- **FBK_2E_9** – 2E sensor.
  1E15 p/cm^2
  Produces ~16000 e^-
- **CNM12-2_75B** – 1E sensor.
  5E14 p/cm^2
  Produces ~13000 e^-

Future Work

- Draw conclusions on the sensor technologies with further analysis.
- Take the next step with the MicroTCA work from real-time event building to real-time tracking.



The Collaboration

- **FNAL**
  S. Kwan, A. Prosser, L. Uplegger, R. Rivera, J. Andresen, J. Chramowicz, P. Tan, C. Lei, A. S. Ito, D. Lincoln, F. Yang, J. Yun, K. Yi, N. Tran, S. Cihangir, Z. Wan
- **Purdue**
  E. Alagoz, O. Koybasi, G. Bolla, D. Bortoletto, M. Bubna, A. Krzywda, K. Arndt
- **Colorado**
  S. Wagner, M. Dinardo, J. Cumalat, F. Jensen
- **Texas A&M**
  I. Osipenkov
- **Milano**
  L. Moroni, D. Menasce, S. Terzo, J. Ngadiuba
- **Torino**
  M. Obertino, A. Solano
- **Mississippi**
  L. Perera
- **Buffalo**
  A. Kumar, R. Brosius
- **IHPC Stasbourg**
  J. M. Brom